**System Noise Temperature** **773 ° K, or 28.9 dB ( ° K)**

(Parameters shown in "bold" are used directly in the interference evaluation.)
The required bandwidth and link margins for these eight systems in both the high band and the low band are indicated in **Table B.1** :

**Table B.1**

**Link Bandwidths and Margins**

| Modulation | Coding | Required Bandwidth, MHz | Link Margin, dB | |
|---|---|---|---|---|
| | | | In High Band | In Low Band |
| 4 φ- PSK | w/o | 22.0 | - 0.80 | - 1.43 |
| 4 φ- PSK | 1/2 | 44.0 | + 0.89 | + 0.26 |
| 4 φ- PSK | 3/4 | 29.3 | + 2.83 | + 2.20 |
| 4 φ- PSK | 7/8 | 25.1 | + 3.56 | + 2.94 |
| 8 φ- PSK | w/o | 14.7 | - 4.44 | - 5.07 |
| 8 φ- PSK | 1/2 | 29.3 | - 2.75 | - 3.38 |
| 8 φ- PSK | 3/4 | 19.6 | - 0.81 | - 1.44 |
| 8 φ- PSK | 7/8 | 16.8 | - 0.08 | - 0.70 |

It is obvious from columns 4 and 5 of the table that there is not excessive C/N margin in the link noise budget for any of the modulation schemes. It is also obvious that there is considerable trade-off available between signal power and signal bandwidth of the proximity-link signal.

Based on these link margins, the EIRP levels indicated above, 25.55 dBW in the high band, and 24.93 dBW in the low band, are required, and that ***the link budgets in the system are very tight, ie. there is not much margin to accommodate interference from other networks.***

For the narrowest bandwidth signal, an 8 φ- PSK signal over a bandwidth of 14.7 MHz, the pfd per MHz bandwidth is 13.88 dBW per 1 MHz in the high band and 13.26 dBW per 1 MHz in the low band. Assuming a peak-to-average power-spectral density of 3 dB over the proximity-link signal, a pessimistic assumption for a digital signal, the maximum dBW per MHz may be as great as 16.9

**dBW per 1 MHz** in the high band and **16.3 dBW per 1 MHz** in the low band.

## B.6 Area of the Earth Covered by a Proximity-Link Antenna

The basic parameters that enter into the determination of the area of the Earth visible from the proximity-link receiver is the altitude of the receiver, the proximity-link receiving antenna's beamwidth, and the elevation angle of the proximity link from the LMCS site. Analysis in Annex D is based on the following values:

| | |
|---|---|
| Receiver Altitudes: | 350 km and 500 km, |
| 3 dB Antenna Beamwidth: | 5.90°, the beamwidth in the lower band, used with the gain 31.93 dBi of the antenna in the lower band, and |
| Elevation Angle: | a parameter of the analysis results. |

The area of the Earth covered by the antenna beam at various elevation angles is described in Table B.2. .Elevation angles considered are ( 3° + n * 6° ) from 3° to 21°, because of the 5.90° beam size, and then every 10° from 30° to 90°. Distances and coverage areas relating to these parameter values are listed in Table B.2

**Table B.2**
**Propagation Distances and Coverage Areas of the Proximity Link Antenna**

| Elevation Angle, Degrees | Receiver Altitude = 350 km | | Receiver Altitude = 500 km | |
|---|---|---|---|---|
| | Distance, km | Coverage Area, km² | Distance, km | Coverage Area, km² |
| 3 | 1,833 | 83,869 | 2,261 | 119,131 |
| 6 | 1,576 | 59,800 | 1,992 | 80,664 |
| 9 | 1,365 | 42,968 | 1,763 | 61,179 |
| 15 | 1,053 | 22,412 | 1,407 | 35,190 |
| 21 | 846 | 12,396 | 1,157 | 21,122 |
| 30 | 652 | 6,017 | 909 | 10,892 |
| 40 | 526 | 3,223 | 741 | 6,120 |
| 50 | 449 | 2,036 | 637 | 4,008 |
| 60 | 401 | 1,492 | 570 | 2,858 |
| 70 | 371 | 1,146 | 529 | 2,482 |
| 80 | 355 | 1,068 | 507 | 2,165 |
| 90 | 350 | 1,022 | 500 | 2,066 |

# Annex C

## Relevant Characteristics of LMCS Systems

### C.1 Introduction

This annex describes the characteristics of Local Multipoint Communications Systems (LMCS) to the extent necessary to determine the parameters of these systems in Equations A.1 to A.5 of Annex A. Those equations with parameter values included are then used in Annex D to determine the aggregate interference into space-station proximity links.

These LMCS characteristics are based on information in Reference [1], a July 1995 Canadian contribution to ITU-R WP 7B/9D, and in Reference [2], a submission by WIC to Industry Canada in September 1993 requesting that the band 27.5-29.5 GHz be so-allocated in the Canadian Allocation Table that it could be used by LMCS systems.

### C.2 General Characteristics and Considerations

An LMCS system is an array of small cells covering in total a large geographical area. Each cell is organized as a star network, with communication between a central hub station and subscriber terminals throughout the cell area; there is no indication of direct communication between subscriber terminals. As described in Figure 1a of Reference [2], (Exhibit C-1) RF channels would be 18 MHz wide separated by 20 MHz, ie. with 4 MHz guard bands between channels. As indicated in Figure 2 of that same reference, (Exhibit C-2) the full bandwidth is used in every cell; limited isolation between cells is obtained by using alternate polarization in adjacent cells and/or off-setting channels in adjacent cells by 10 MHz, ie. by 1/2 a channel-separation width. Clear-air attenuation between cells and antenna directivity will presumably provide any additional required isolation between co-frequency transmissions in neighbouring cells. (There is no evaluation of the viability of this approach in this report, only a summary of the system as described by WIC to Industry Canada.)

The traffic in these star networks within individual cells is a combination of

* hub-to-subscriber television program distribution,
* simplex, full-duplex, or half-duplex video communication between subscriber and hub,
* simplex, half-duplex, and/or full-duplex voice and data transmission between subscriber terminal and hub station.

Indications are that a majority of the traffic on the networks would be hub-to-subscriber distribution of television programs. The inter-network interference analysis is done on the assumption that this is the traffic that is causing interference into the proximity-link system, at least in the 14.7 to 44 MHz bandwidths of a proximity-link channel.

The hub station uses an antenna system that is omni-directional in azimuth, but very highly directional in elevation, pointing towards the subscribers at the same or possibly lower altitudes than the hub-station antenna that would presumably be mounted on a tower to avoid ground scatter to the extent possible.

Subscriber terminals use high-gain spot-beam antennas pointed towards the hub station. The directivity of these antennas is a significant factor in allowing full use of the complete band in each LMCS cell.

Reference [1] describes two possible implementations of LMCS networks, System LMCS "A" without adaptive power control and System LMCS "B" with adaptive power control. System A presumably has enough link-budget margin during clear weather to "burn through" the attenuation during most rain events. As discussed in Annex A, the interference analysis is done on the basis of clear-air conditions. Interference is calculated under clear-air conditions, based on the results obtained in the analysis reported in Section 3.3 of Reference [1] that **"increased attenuation due to rain.....results in the interference calculated under clear-sky conditions as being the worst case."** Thus determination of the magnitude of the interference at the proximity-link receiver includes the effect of clear-air attenuation, but not attenuation due to rain.

Canadian consideration of the implementation of LMCS systems in a portion of the 25.25-27.5 GHz band, rather than a portion of the 27.5-29.5 GHz band, is presumably not only for possible implementation in Canada, but for foreign sales of a Canadian product. Thus in this analysis it is assumed that interference into space-station proximity links may occur anywhere in the world. On that basis, a worst-case interference analysis is carried out in which the interference occurs from a portion of the Earth in which there is heavy rainfall, ie. that the interference occurs from a "Rain-Zone M" area. To do otherwise, ie. to consider only rain zones in Canada, would ignore the possibility that LMCS systems might eventually be implemented in high-rainfall areas as a result of Canadian initiative to develop 26 GHz LMCS systems for foreign application.

## C.3 Detailed Characteristics of LMCS Systems

In this section the specific characteristics used to determine the magnitude of the interference at the proximity-link receiver are described, based on references [1] and [2].

**LMCS Channel Bandwidth:** 18 MHz, within a frequency plan with 20 MHz channel separation.

Adjacent service areas use channelization plans offset by 10 MHz.(See **Exhibits C-1 and C-2.**)

**Polarization of Transmissions**: Polarization is either horizontal or vertical. Opposite polarizations are used in adjacent cells.(See **Exhibit C-2**).

**Link Noise Budgets:** The link noise budgets of two types of LMCS system, denoted as LMCS-A and LMCS-B in Reference [1], are as indicated in Table C.1 for the transmission of television signals. This information is taken from Table 2.3 of Reference [1], and is specified on a per-1 MHz basis rather than the total over the 18 MHz bandwidth:

**Table C.1**

**Hub-to-Subscriber Link Budgets of Systems LMCS-A and LMCS-B**

| Parameter | LMCS-A Characteristic | LMCS-B Characteristic |
|---|---|---|
| Maximum Tx Power, dBW / 1 MHz | - 17.60 | - 12.30 |
| Maximum APC, dB | 0.0 | 20.0 |
| Hub Antenna Gain, dBi | 12.0 | 12.0 |
| Subscriber Antenna Gain, dBi | 31.0 | 34.0 |
| Path Attenuation during rain, dB | 148.5 | 150.8 |
| Received Power, dBW / 1 MHz | - 123.1 | - 117.1 |
| Subscriber Thermal Noise, dBW/1 MHz | - 138.0 | - 136.0 |
| Minimum C/N with rain | 14.9 | 21.9 |

Further consideration will be based on the LMCS-A system, as it is a network of LMCS-A systems over a number of cells that would cause the greater interference into the receivers of a proximity-link system.

**Hub EIRP:** + 6.95 dBW over 18 MHz, based on information in Table C.1 above,
ie. - 17.60 + 10 * Log (18) + 12.0 = 6.95

**LMCS Cell Size:** The size of LMCS cells would vary as a function of the amount of rain attenuation encountered in the area. In rain-zone N, taken as the "worst-case from a perspective of interference into proximity links" in this study, the cell radius would be 4 km. (See Figure 1 of Reference [1], **Exhibit C-3.**) The rain zones of the world are shown in **Exhibit C-5**, Figures 1 to

3 of ITU-R from Recommendation 837 (1992) [9]. As shown in those figures, large areas of all ITU Regions in lower latitudes are in Rain Zone N .

**Hub Antenna Characteristics:** The hub antenna is omni-directional in azimuth, but very directive in elevation. Its gain in the elevation direction is as shown in Figure 3 of Reference [1], (See Figure 3 of Reference [1], **Exhibit C-3**.) However, that figure does not take into account scatter of the hub transmission in the direction of the proximity link. Section 4.2 of Reference [1] suggests that this scatter interference would be equivalent to that "with an EIRP 11 dB below the hub transmit power level." This effect is approximated in this study by limiting the antenna-pattern gain shown in Exhibit C-3 to - 11 dB with respect to its maximum gain. Based on this approach the gain of the Hub antenna at different elevation angles is as shown in Table C.2

**Table C.2**

**Effective Hub Antenna Gain as a Function of Elevation Angle**

| Elevation Angle, Degrees above Horizon | 0 | 1 | 2 | 3 | 4 | ≥ 4.5 |
|---|---|---|---|---|---|---|
| Antenna Discrimination, dB | 1 | 3 | 5 | 7 | 9 | 11 |

**Clear-Air Attenuation:** At low angles of propagation, clear-air attenuation. Clear-air attenuation as a function is given in Figure 11 of Reference [1], shown in **Exhibit C-4**. The B (no rain) curve of that figure is used in the interference analysis in **Annex D**. The attenuation at different elevation angles is as indicated in Table C.3:

**Table C.3**

**Clear-Air Attenuation at Different Elevation Angles**

| Elevation Angle, Degrees | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Clear-Air Attenuation, dB | 17 | 12 | 8 | 6 | 4.5 | 3.8 | 3.3 | 2.8 | 2.5 |

| Elevation Angle, Degrees | 10 | 12 | 14 | 17 | 20 | 25 |
|---|---|---|---|---|---|---|
| Clear-Air Attenuation, dB | 2.0 | 1.6 | 1.3 | 1.2 | 1.0 | 0.8 |

Exhibit C-1

Figure 1B of Reference [2]

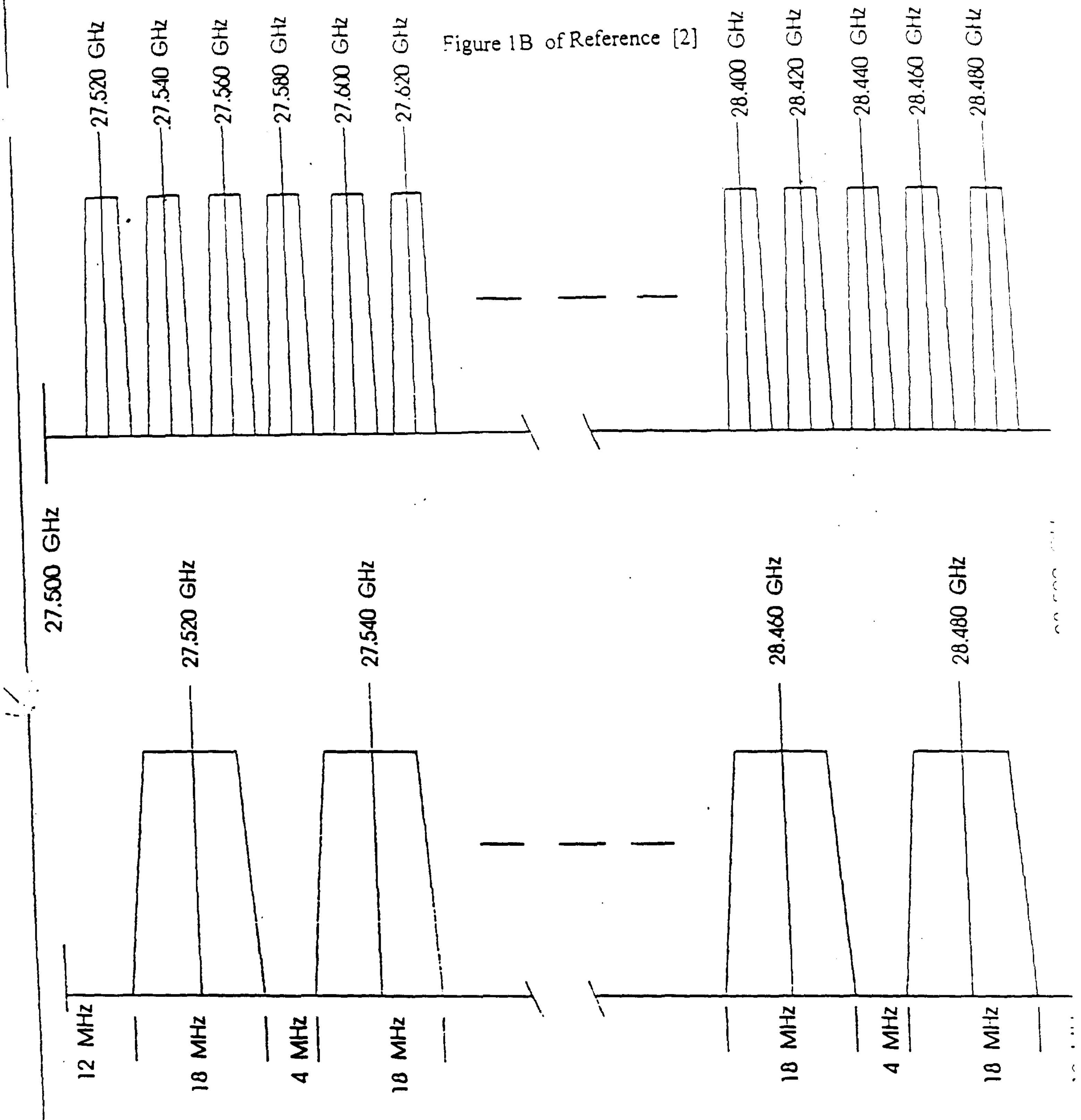



FIGURE 1B

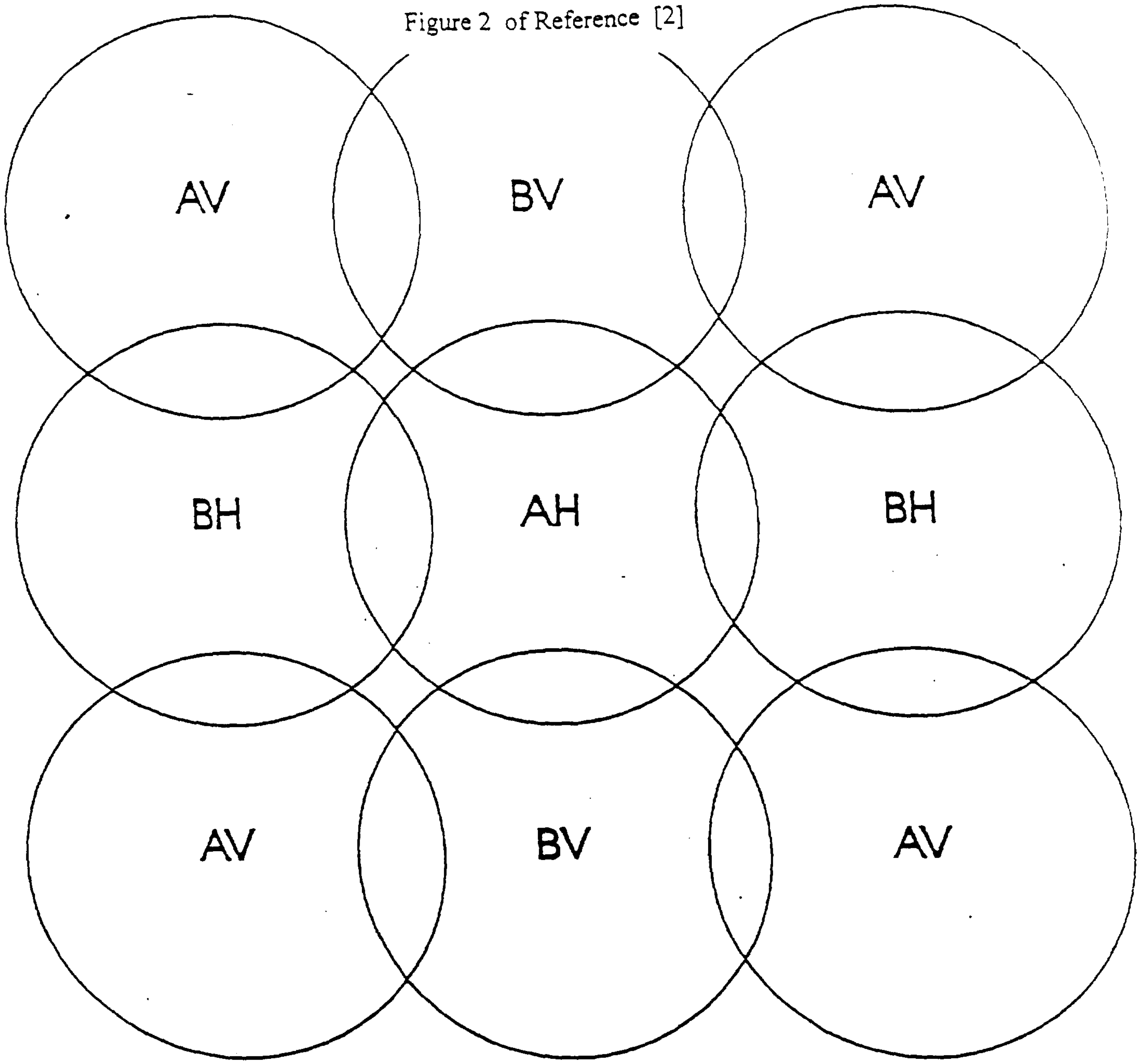
CHANNEL FREQUENCY ASSIGNMENTS
OFFSET FREQUENCY PLAN
LOCAL MULTIPOINT DISTRIBUTION
SERVICES (CELLULARVISION)
WIC WESTERN INTERNATIONAL COMMUNICATIONS L

PROJECT #36001 SEPTEMBER 7, 19

DE.M ALLEN & ASSOCIATES LTD
CONSULTING ENGINEERS

Exhibit C-2

Figure 2 of Reference [2]




A - Frequency Scheme A - 27.510, 27.530, 27.550, —
B - Frequency Scheme B - 27.520, 27.540, 27.560, —
H - Horizontal Polarization
V - Vertical Polarization

FIGURE 2

CELLULAR FREQUENCY AND POLARIZATION
ASSIGNMENT PLAN
LOCAL MULTIPOINT DISTRIBUTION
SERVICES (CELLULARVISION)
WIC WESTERN INTERNATIONAL COMMUNICATIONS LT

PROJECT #36001 SEPTEMBER 7, 199

D.E.M. ALLEN & ASSOCIATES LTD
CONSULTING ENGINEERS

# Exhibit C-3

Figures 1 and 3 of Reference [1]

Fig. 1: LMCS Cell Size and Hub Transmitter Power as a Function of Rain Climatic Zone (LMCS 'A')

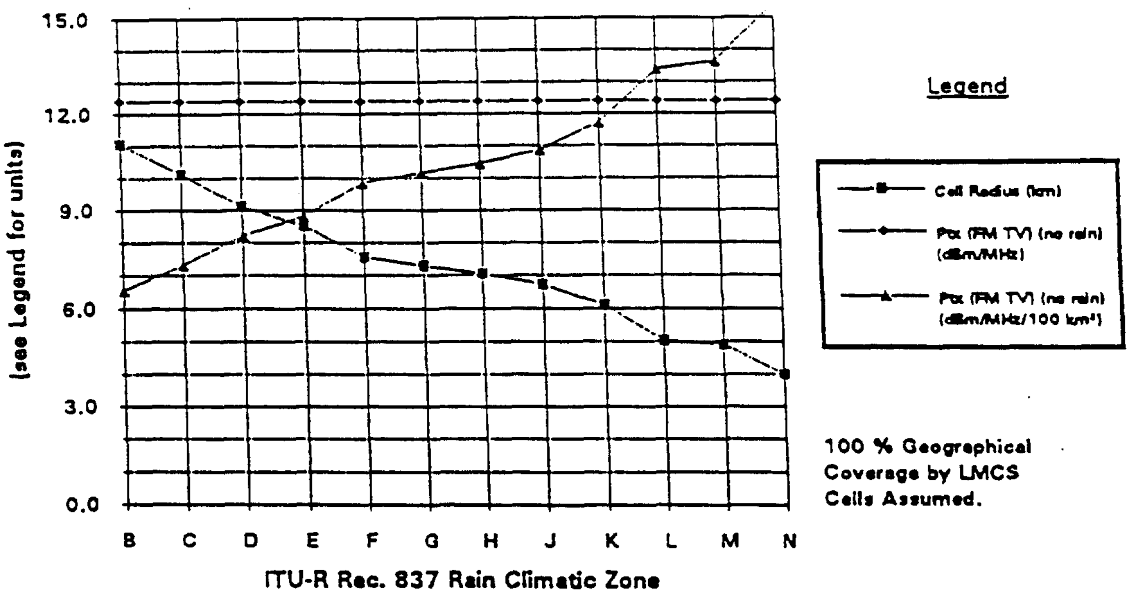
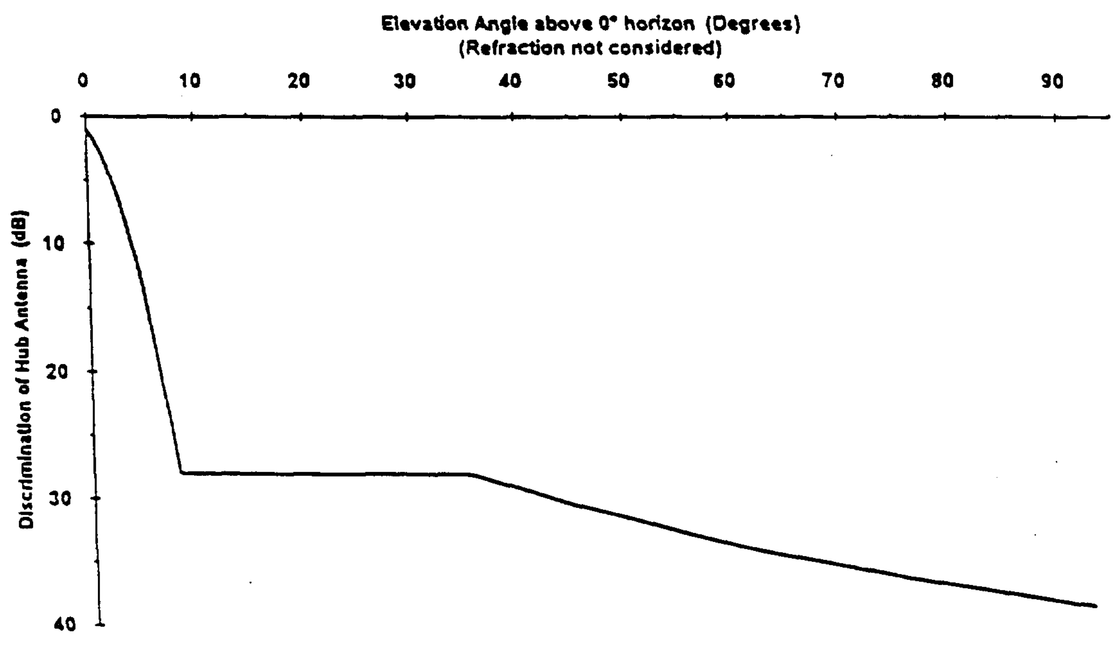



Figure 3: LMCS 'A' Hub Antenna Pattern

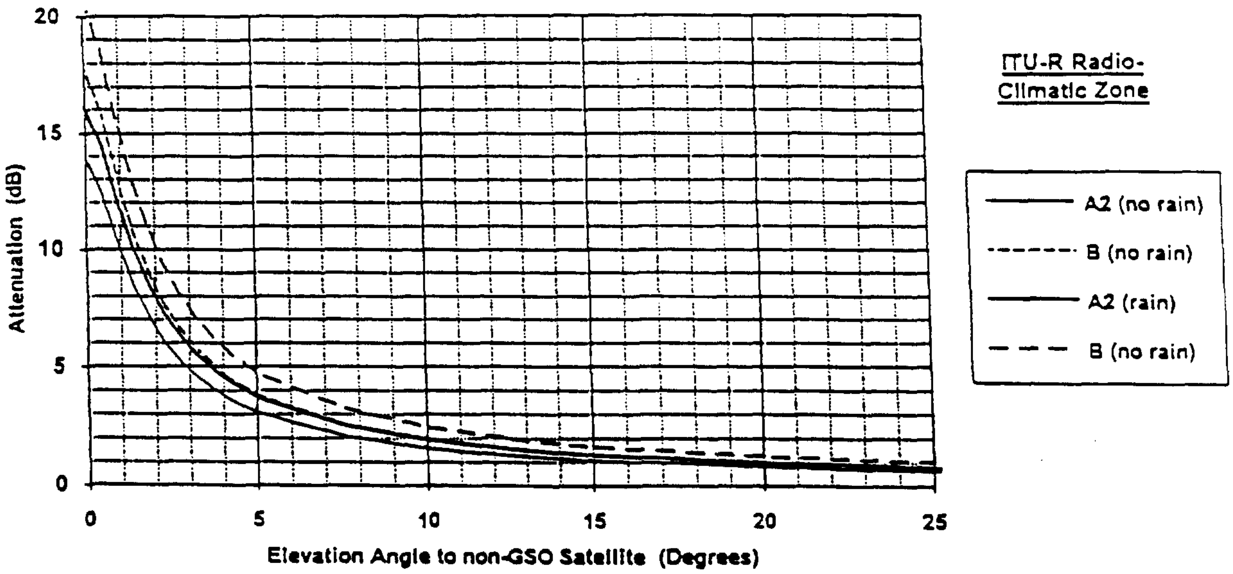



Note: Maximimum Gain Assumed to be -1.9° below horizontal for a typical installation

# Exhibit C-4

Figure 11 of Reference [1]

Fig. 11: Rec. ITU-R PN.676-1 Attenuation Due to Atmospheric Gases as a Function of Elevation Angle




Frequency = 26.375 GHz, Ground Elevation = 360 m, Pressure = 1013 hPa, Temperature = 15°

# Exhibit C-5

FIGURE 1

(See Table 1)

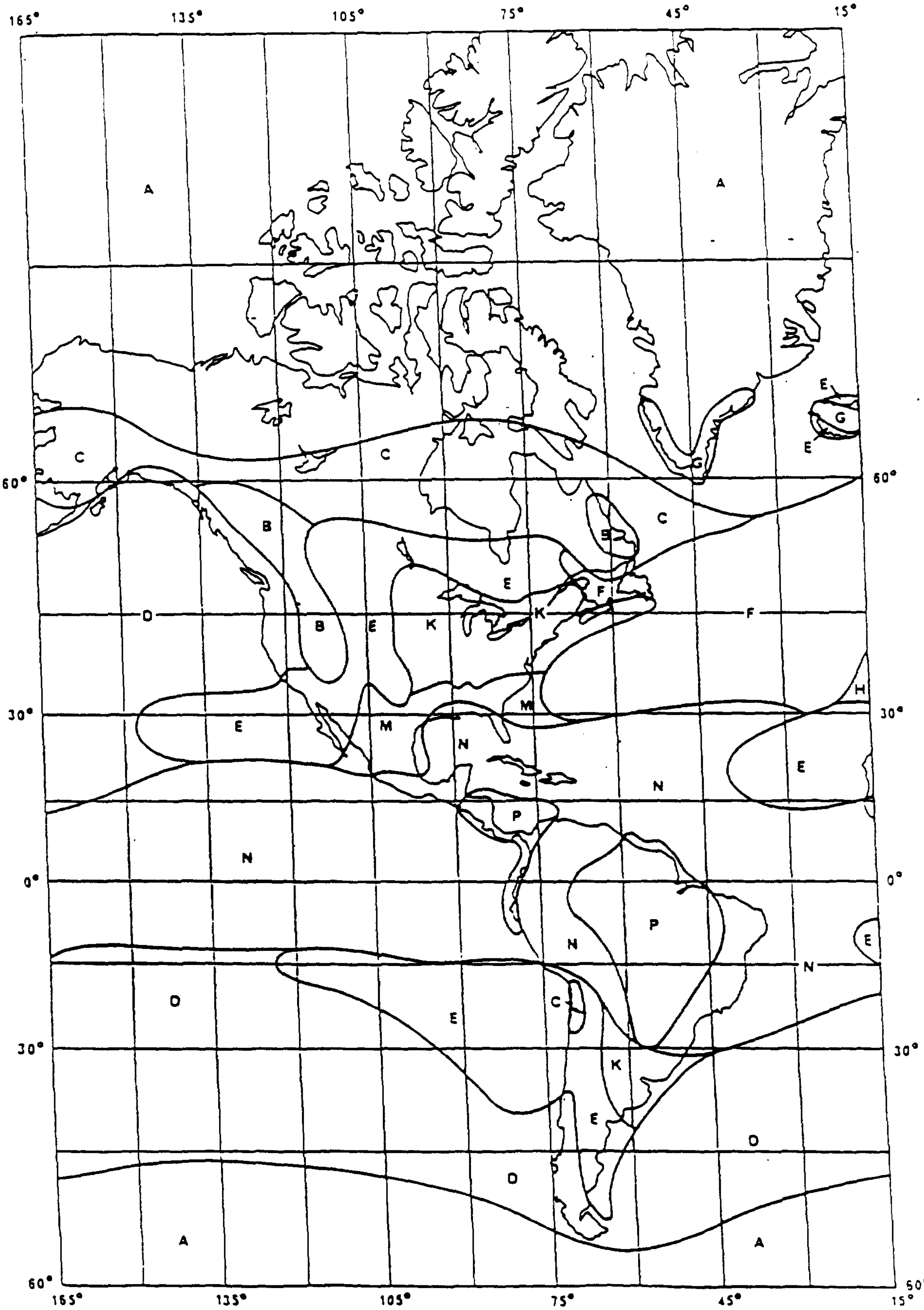
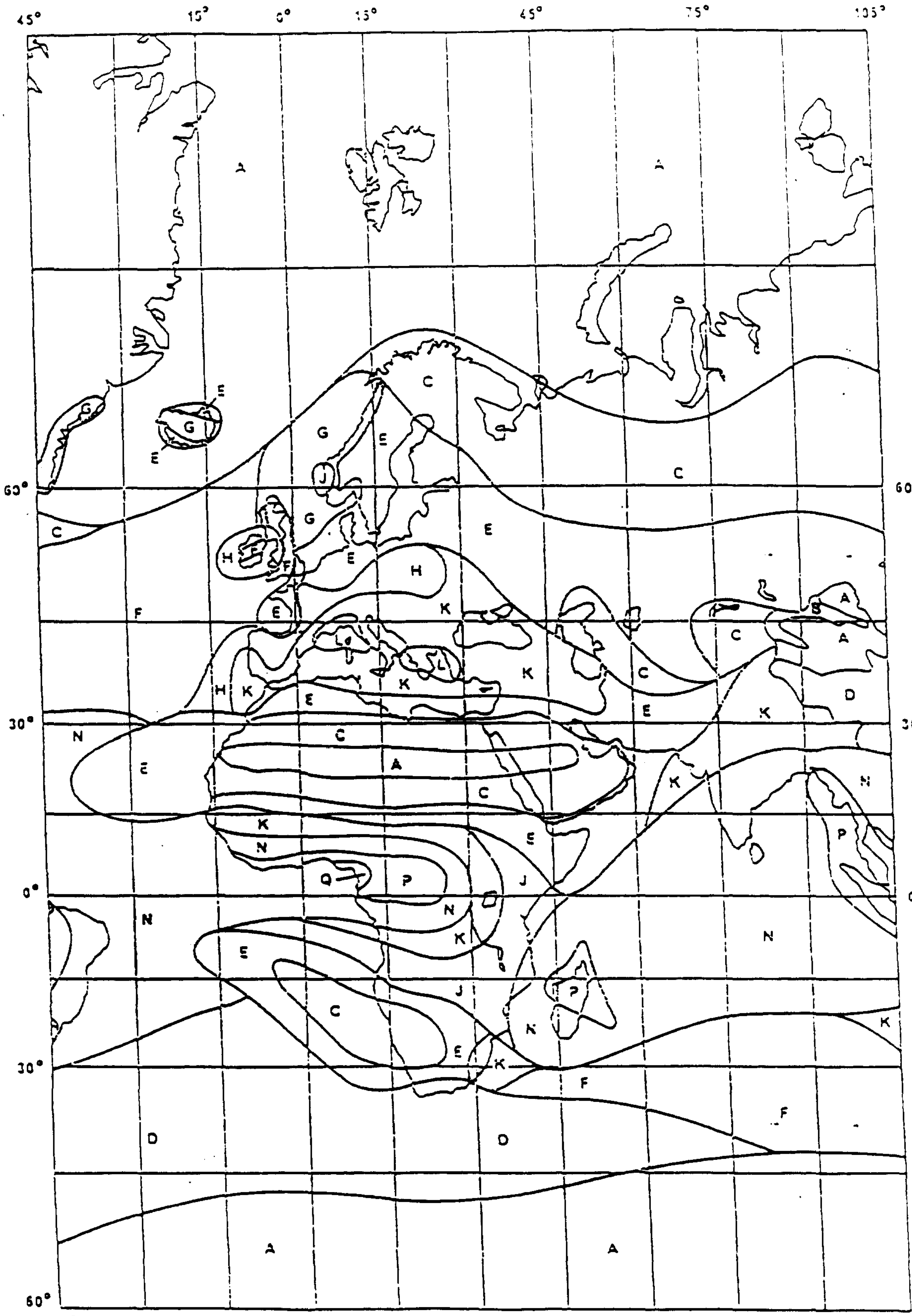


**Exhibit C-5 ( Continued )**

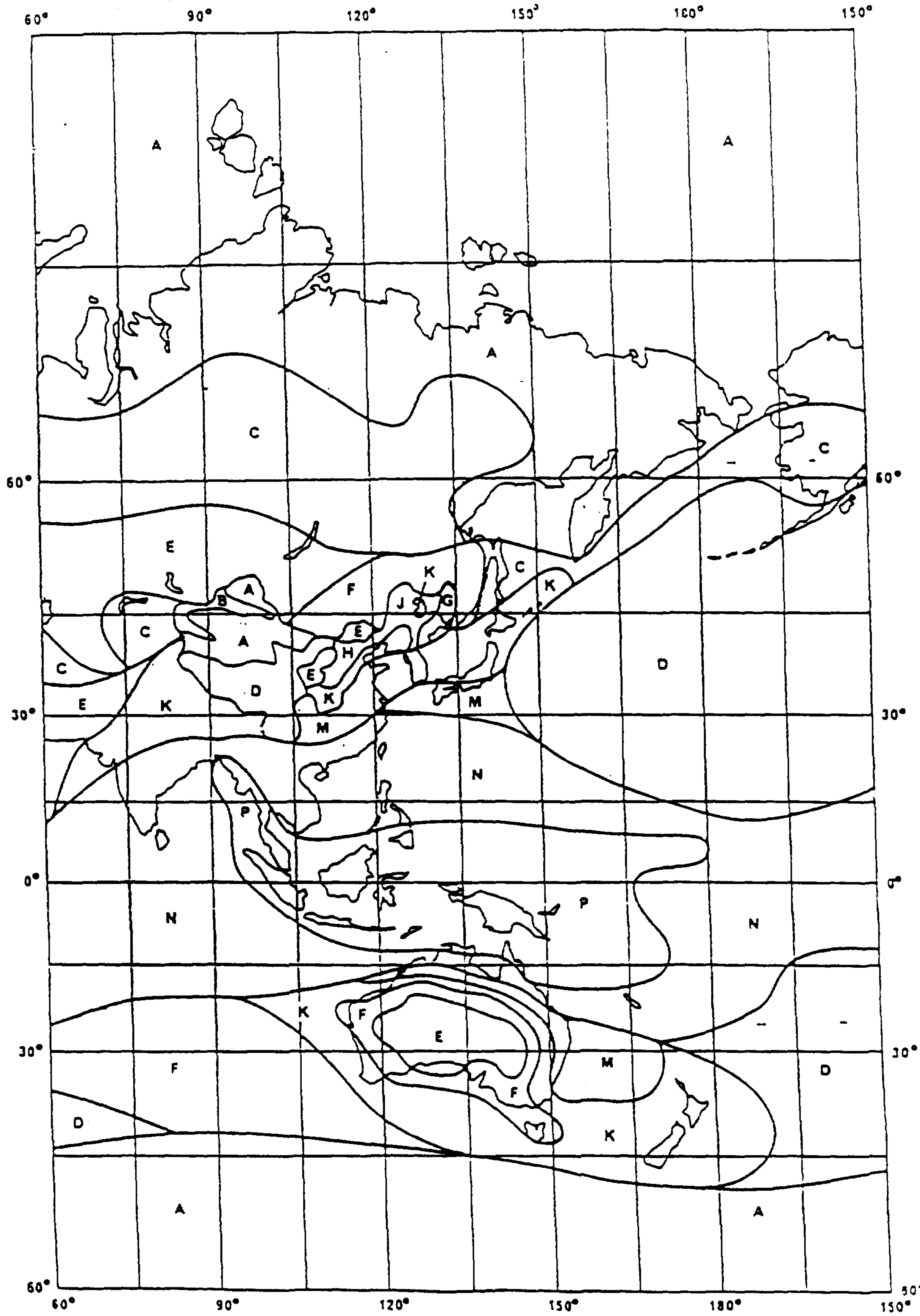
(See Table 1)



## Exhibit C-5 (Continued)

FIGURE 3

(See Table 1)



# Annex D

## Co-Channel Interference From LMCS Systems into Proximity Links

### D.1 Introduction

In this annex the aggregate interference from all LMCS systems in the receiving antenna of a proximity-link system is estimated. This interference is compared with the thermal noise in the proximity-link system, and is stated in terms of the equivalent temperature of wide-band Gaussian noise, since that would be the characteristic of the aggregate interference from a large number of LMCS systems.

This interference estimation uses the relations developed in Annex A, the characteristics of proximity-links as described in Annex B, and the characteristics of LMCS systems as described in Annex C.

The basic equation describing the aggregate interference into the proximity-link receiver is described in Section D.2. Numerical values of each of the terms in the interference equation are discussed in Section D.3. In some cases the parameter values are available from Annexes B and C; in other cases the data in those annexes requires interpretation. The actual estimation of the magnitude of the interference is made in Section D.4.

### D.2 Basic Relations

The aggregate interference at the proximity-link receiver from all LMCS systems in the receiving antenna beam is given by Equation

$$I_{agg}(\theta, f) = EIRP_{LMCS} - A_{Clear\,Air}(\theta) - D_{LMCS,PROX}(\theta) - 92.5 - 20\,\mathrm{Log}(f) - 20\,\mathrm{Log}(d_1)$$
$$+ G_{PROX}(0) - D_{Polarization} + 10\,\mathrm{Log}(N_f) + 10\,\mathrm{Log}(A_P / A_L) \quad \text{.................... A.5.}$$

where

$EIRP_{LMCS}$ is the EIRP of a single LMCS transmission;

$A_{Clear\,Air}(\theta)$ is the clear-air attenuation between the LMCS transmitter and the proximity-link receiver, at an elevation angle of $\theta$ degrees;

$\theta$ is the elevation angle of the proximity-link receiver as seen from the LMCS transmitter;

$D_{LMCS, PROX}(\theta)$ is the discrimination of the LMCS transmitting antenna in the direction of the proximity-link receiver, at an elevation angle of $\theta$ degrees;

$f$ is the carrier frequency in GHz;

$d_l$ is the separation between LMCS transmitter and the proximity-link receiver in km.;

$G_{PROX}(0)$ is the boresite (worst case) gain of the proximity-link receiving antenna;

$D_{Polarization}$ is the reduction in the received interference power due to different signal polarization being used by the LMCS and proximity-link systems;

$N_f$ is the number of LMCS carriers in the bandwidth of the proximity-link system;

$A_L$ is the area of an LMCS cell; and

$A_P$ is the effective area "illuminated" by the proximity-link receiving antenna.

This interference level is compared with the thermal noise magnitude

$$N = 10 * \mathrm{Log}(k) + 10\,\mathrm{Log}(B) + 10\,\mathrm{Log}(T) \quad \text{.......} \quad \text{D.1},$$

where

$k$ is Boltzman's constant, equal to - 228.6 dB;

$B$ is the bandwidth of the proximity-link system; and

$T$ is the system noise temperature of the proximity-link system.

## D.3 Values of the Above Parameters

**$EIRP_{LMCS}$ : As indicated in Section C.3 of Annex C, parameters of the LMCS-A are used,** because this system does not use APC. As a result, that system has a higher EIRP in clear-air conditions, **6.95 dBW over an 18 MHz band.**

$A_{Clear\ Air}(\theta)$ : This attenuation is given in Table C.3, and is shown graphically in Exhibit C-4.

$\theta$ : As discussed in Section B.6 of Annex B, the analysis is done at a number of elevation angles, at 3°, 6°, 9°, 15°, 21°, 30°, 40°, 50°, 60°, 70°, 80°, and 90°.

**$D_{LMCS, PROX}(\theta)$ :** The discrimination of the LMCS hub antenna in the elevation plane is indicated in Figure 3 of Exhibit C-3. To account for scatter this antenna discrimination is artificially limited to 11 dB. The values used are indicated in Table C.2 of Annex C.

**f:** The carrier frequency considered is 25.40 GHz, the centre of the lower band.

**$d_i$:** The distances from LMCS transmitter to proximity-link receiver are approximated to be constant for each elevation angle parameter value. These distances are given in Table B.2 of Annex B.

**$G_{PROX}(0)$:** The boresite gain of the proximity-link in the low band is 31.9 dBi. However, a correction is required to account for the fact that not all LMCS transmitters are in the centre of the beam. The same approach is used as described in Section 4.2 of Reference [1], ie. to consider only LMCS systems within the 3 dB contour, and in this area to decrease the antenna gain by 1.2 dB. As a result, the value of $G_{PROX}(0)$ used in the analysis is **30.7 dBi.**

**$D_{Polarization}$ :** The proximity link is likely to use circular polarization. However, because LMCS systems use both horizontal and vertical polarizations in adjacent areas, the Proximity-link polarization is not a factor. The summation is correct by using **3 dB** discrimination.

**$N_f$ :** The LMCS bandwidth is 18 MHz. The narrowest proximity-link bandwidth is 14.7 MHz. However, as discussed in Table 3 of Reference [1], TV/FM signals transmitted over an LMCS link are quite peaked, with maximum-to-average pfd values of about 10:1. on that basis, $N_f$ is set at unity, or **0 dB.**

**$A_L$ :** As indicated in Figure 1 of Exhibit C-3, the LMCS service-area radius is a function of the local rain conditions. Since the space-station must operate over any territory on Earth, a worst-case condition of Rain-Zone M is assumed, with a service area radius of 4 km or a **50.3 km²** area.

**B:** As discussed above in considering $N_f$, the bandwidth chosen for the analysis is **14.7 MHz.**

**T:** The equivalent system thermal noise temperature is **773° K**, or **28.9 dB ( ° K ).**

**$A_P$ :** The area actually covered by the receiving antenna of the proximity-link is given in columns 3 and 5 of **Table B.2 of Annex B**. However, as discussed in Section 4.2 of Reference [1], not all of that area would be completely saturated with LMCS systems. Reference [1] weighted this area with a factor 0.333 to account for the fact that less than 1/3 of the land mass would be served by LMCS systems. However, this "you are fine on the average" seems somewhat optimistic, in that if a large metropolitan area is completely served, and the antenna is pointing at that area, it is no consolation that "on the average" it is in good shape. Because of this, a variation of the one-third rule was used, as follows:

The area of a large metropolitan area was estimated, and assumed to be completely served. The area in southern Ontario near Toronto, from Newcastle to Hamilton, was used as a basis to estimate the size of such an area. That area is estimated to cover about 6,500 km$^2$. This area was increased by 50 % to account for interference from very large metropolitan areas in tropical areas in Rain Zone N. Based on this finding and the information in Reference [1], the "effective area" was estimated by the following equation:

$$A_E = A_A \text{ , if } A_A \leq 9{,}750 \text{ km}^2\text{, or}$$

$$= 9{,}750 + 0.333 * ( A_A - 9{,}750 ) \quad \ldots\ldots \text{D.2,}$$

where $A_A$ is the actual area in Table B.1 and $A_E$ is the effective area to be used in Equation A.5 for the parameter $A_P$. This is the same approach as that in Reference [1], except that at higher latitudes the danger of pointing directly towards an extensive metropolitan area is not discounted. The effective areas used in the analysis are given in Table D.1 on the following page. As well, the term { 10 Log ( $A_P$ / $A_L$ ) } is determined, using the above-discussed value **50.3 km²** for the parameter $A_L$.

## D.4 Evaluation of the Interference

With the substitution of the above parameters in Equation A.5 that are not dependent on the elevation angle $\theta$, that equation

$$I_{agg}(\theta, f) = EIRP_{LMCS} - A_{Clear\,Air}(\theta) - D_{LMCS,\,PROX}(\theta) - 92.5 - 20 \,\text{Log}(f) - 20\,\text{Log}(d_1)$$

$$+ G_{PROX}(0) - D_{Polarization} + 10\,\text{Log}(N_f) + 10\,\text{Log}(A_P / A_L) \quad \ldots\ldots \text{A.5}$$

becomes

$$I_{agg}(\theta) = 6.95 - A_{Clear\,Air}(\theta) - D_{LMCS,\,PROX}(\theta) - 92.5 - 28.10 - 20\,\text{Log}(d_1)$$

$$+ 30.7 - 3 + 0 + 10\,\text{Log}(A_P / A_L)$$

$$= -85.95 - A_{Clear\,Air}(\theta) - D_{LMCS,\,PROX}(\theta) - 20\,\text{Log}(d_1) + 10\,\text{Log}(A_P / A_L) \quad \ldots \text{D.3.}$$

This equation is evaluated in Table D.2 for proximity links at 350 km altitude, and in Table D.4 for proximity links at 500 km altitude. The resulting values of $I_{agg}$ at the different angles is converted into an effective "noise temperature" over the 14.7 MHz bandwidth using Eq'n D.1, and in a separate representation of the interference it is compared with the thermal noise power N , again using Eq'n D.1 to determine the thermal noise power.

**Table D.1**

**Effective Areas Covered by Proximity-Link Antennas**

| Elevation Angle, Degrees | Proximity-Link Altitude = 350 km | | | Proximity-Link Altitude = 500 km | | |
|---|---|---|---|---|---|---|
| | Actual Area km$^2$ | Effective Area, km$^2$ | 10 Log ( $A_P$ / $A_L$ ) | Actual Area, km$^2$ | Effective Area, km$^2$ | 10 Log ( $A_P$ / $A_L$ ) |
| 3 | 83,869 | 34,432 | 28.35 | 119,131 | 46,174 | 29.63 |
| 6238 ° K | 59,800 | 26,417 | 27.20 | 80,664 | 33,364 | 28.22 |
| 9 | 42,968 | 20,812 | 26.17 | 61,179 | 26,876 | 27.28 |
| 15 | 22,412 | 13,966 | 24.44 | 35,190 | 18,222 | 25.59 |
| 21 | 12,396 | 10,500 | 23.20 | 21,122 | 13,537 | 24.30 |
| 30 | 6,017 | 6,017 | 20.78 | 10,892 | 10,130 | 23.04 |
| 40 | 3,223 | 3,223 | 18.07 | 6,120 | 6,120 | 20.85 |
| 50 | 2,036 | 2,036 | 16.07 | 4,008 | 4,008 | 19.01 |
| 60 | 1,492 | 1,492 | 14.72 | 2,858 | 2,858 | 17.54 |
| 70 | 1,146 | 1,146 | 13.58 | 2,482 | 2,482 | 16.93 |
| 80 | 1,068 | 1,068 | 13.27 | 2,165 | 2,165 | 16.34 |
| 90 | 1,022 | 1,022 | 13.08 | 2,066 | 2,066 | 16.14 |

**Table D.2**

**Interference From LMCS Systems into A Proximity Link Receiver at a 350 km Altitude**

| Elevation Angle $\theta$, Degrees | $- A_{Clear Air} (\theta)$ | $- D_{LMCS, PROX} (\theta)$ | - 20 Log ($d_I$) | 10 Log ( $A_P$ / $A_L$ ) | $I_{agg} (\theta)$ dB | 10 Log($T_I$) dB | $I_{agg}$ / N dB |
|---|---|---|---|---|---|---|---|
| 3 | 6 | 7 | 65.26 | 28.35 | - 135.86 | 21.07 | - 7.83 |
| 6 | 3.3 | 11 | 63.95 | 27.20 | - 137.00 | 19.93 | - 8.97 |
| 9 | 2.2 | 11 | 62.70 | 26.17 | - 135.68 | 21.25 | - 7.65 |
| 15 | 1.25 | 11 | 60.45 | 24.44 | - 134.21 | 22.72 | - 6.18 |
| 21 | 1.0 | 11 | 58.55 | 23.20 | - 133.30 | 23.63 | - 5.27 |
| 30 | 0.75 | 11 | 56.28 | 20.78 | - 133.20 | 23.73 | - 5.17 |
| 40 | 0.65 | 11 | 54.42 | 18.07 | - 133.95 | 22.98 | - 5.95 |
| 50 | 0.60 | 11 | 53.04 | 16.07 | - 134.52 | 22.41 | - 6.49 |
| 60 | 0.50 | 11 | 52.06 | 14.72 | - 134.79 | 22.14 | - 6.76 |
| 70 | 0.40 | 11 | 51.39 | 13.58 | - 135.16 | 21.97 | - 7.13 |
| 80 | 0.30 | 11 | 51.00 | 13.27 | - 134.98 | 21.95 | - 6.95 |
| 90 | 0.30 | 11 | 50.88 | 13.08 | - 135.05 | 21.88 | - 7.02 |

**Table D.3**

**Interference From LMCS Systems into A Proximity Link Receiver at a 500 km Altitude**

| Elevation Angle θ, Degrees | $- A_{Clear\ Air}(\theta)$ | $- D_{LMCS,\ PROX}(\theta)$ | - 20 Log ($d_1$) | 10 Log ( $A_P / A_L$ ) | $I_{agg}(\theta)$ dB | 10 Log($T_I$) dB | $I_{agg}/N$ dB |
|---|---|---|---|---|---|---|---|
| 3 | 6 | 7 | 67.09 | 29.63 | - 136.41 | 20.52 | - 8.38 |
| 6 | 3.3 | 11 | 65.99 | 28.22 | - 138.02 | 18.91 | - 9.99 |
| 9 | 2.2 | 11 | 64.93 | 27.28 | - 136.80 | 20.13 | - 8.77 |
| 15 | 1.25 | 11 | 62.97 | 25.59 | - 135.58 | 21.35 | - 7.55 |
| 21 | 1.0 | 11 | 61.27 | 24.30 | - 134.92 | 22.01 | - 6.89 |
| 30 | 0.75 | 11 | 59.17 | 23.04 | - 133.83 | 23.1 | - 5.80 |
| 40 | 0.65 | 11 | 57.40 | 20.85 | - 134.15 | 22.78 | - 6.12 |
| 50 | 0.60 | 11 | 56.08 | 19.01 | - 134.62 | 22.31 | - 6.59 |
| 60 | 0.50 | 11 | 55.12 | 17.54 | - 135.03 | 21.90 | - 7.00 |
| 70 | 0.40 | 11 | 54.47 | 16.93 | - 134.89 | 22.04 | - 6.86 |
| 80 | 0.30 | 11 | 54.10 | 16.34 | - 135.01 | 21.92 | - 6.98 |
| 90 | 0.30 | 11 | 53.98 | 16.14 | - 135.09 | 21.84 | - 7.06 |

Columns 8 of Tables D.2 and D.3 indicate that when the proximity link is at a 350 km altitude the worst-case aggregate-to-thermal-noise ratio in the proximity-link receiver is - 5.17 dB. This occurs only a rather narrow elevation-angle range near 30°. For most of the elevation angles the aggregate I/N ratio is less than - 6 dB. When the proximity-link altitude is increased to 500 km the results are slightly better but not significantly different; the greatest aggregate I/N ratio is - 5.8 dB, and is less than - 7 dB for most elevation-angle values.

There is no ITU-R Recommendation on the maximum permissible interference from terrestrial fixed systems into proximity links operating in the Inter-Satellite service. However, aggregate interference levels in the order of - 5.17 dB below the thermal noise level of the proximity link provide a significant impairment to the operation of the links. Aggregate interference level limits in other services such as the fixed-satellite service are in the order of 25 % of the total interference in the communications path, or - 4.8 dB with respect to the thermal noise in the link. The aggregate interference level of - 5.17 dB with respect to the proximity link's thermal noise level is of this order of magnitude, without taking into account any other inter-system interferences to which the proximity link may be subject. Thus the complete hypothetical inter-system interference budget of the proximity link would be absorbed by terrestrial LMCS systems.

Another way to evaluate the severity of this aggregate interference is to estimate the reduction in range of the proximity link caused by the addition of the aggregate interference from the LMCS systems. If the nominal range of the proximity link was 50 km without the presence of interference from LMCS systems, and if the range had to be reduced to achieve the same C / ( I+N ) in the presence of LMCS interference, interference 5.17 dB below the thermal noise level would increase the system ( I+N ) by 30.4 % or 1.15 dB. *To achieve the same system C / (I+N) without changing any system parameter other than system operating range, that range would have to be reduced in the worst case* ***from 50 km to 43.8 km.***

The aggregate I/N ratios range from about - 5 dB to about - 10 dB at different altitudes and elevation angles. The reduction in range over that aggregate I/N range indicated in Tables D.2 and D.3 is shown in Table D.4, based on a range of 50 km [3] without interference :

**Table D.4**

**Reduction in Maximum Range Due to LMCS Interference**

| Aggregate I / N Ratio, dB | - 5 | - 6 | - 7 | - 8 | - 10 |
|---|---|---|---|---|---|
| Maximum Range of System, km | 43.6 | 44.7 | 45.6 | 46.5 | 47.7 |

Based on this evidence, the worst-case aggregate I/N of - 5.17 dB is a significant interference, and if combined with other interference from other networks operating with primary status in the band, could make the proximity-link system unviable.

## D.5 Variational Analysis: Interference with Different System Parameter Assumptions

In this section the assumptions and parameter values used in the analysis are re-examined. This analysis does not attempt to re-design the basic proximity-link systems described in Reference [3], or the LMCS systems described in References [1] and [2]. Rather, it considers the effect of system choices made as part of the analysis in this report. That analysis uses worst-case values, in an attempt to determine if there are conditions in which interference from LMCS systems would in fact be harmful. These assumptions are re-examined in this section.

The assumptions re-examined are:

* the assumption that the interfering LMCS system is the LMCS-A type rather than LMCS-B type, as described in Reference [1];
* basing the analysis on use of the Low band rather than the High band, as defined in Reference [3];
* basing the analysis on proximity-link receivers being at 350 km and 500 km altitude;
* basing the analysis on use of the 8 φ- PSK system without channel encoding and a corresponding 14.7 MHz bandwidth, rather than a system with different modulation, coding, and RF bandwidth;
* the assumption that the interfering LMCS systems are in Rain Zone N, rather than some other rain zone; and
* the assumption that the largest fully-saturated metropolitan area is 9,750 km.

### D.5.1 Effect of Variation in LMCS Type

The basic difference between LMCS types as described in Reference [1], from an inter-service interference perspective, is that LMCS-B uses automatic power control to overcome the effect of rain, and LMCS-A does not. Because of that difference, LMCS-A systems transmit 7 dB greater power in clear-air than LMCS-B systems. It is in clear-air conditions that the maximum interference is experienced by the space system, because of the lack of attenuation in the terrestrial-to-space path. Thus the LMCS-A system is the worst system from the perspective of inter-service interference. That system was assumed in the above analysis.

### D.5.2 Variation of Interference When Using High Band Rather then Low Band

The above analysis was based on the use of Low Band, ie. 25.25 - 25.55 GHz, rather than High Band, ie. 27.1-27.5 GHz. The basic differences between the two bands are the higher gain of the proximity-link antenna in the higher band, and the larger so-called free-space loss in the higher band. Reference [3] states that the proximity-link antenna has a 32.55 dBi gain in the high band, and a 31.93 dBi gain in the low band. This 0.62 dB difference in antenna gains in the two bands is precisely the difference 20 * Log ( 27.3 / 25.4 ), the difference in free-space loss in the two bands. This is logical, because the 20 Log ( f ) factor in the free-space loss is to account for the differences in gain at different frequencies of antennas with the same area. Thus, as a first approximation there is no difference in the interference that would be experienced in the two bands.

However, there is a secondary effect. The above is strictly true for a **single** LMCS interferer. However, a lower gain antenna has a wider beam-width, in this case 5.90° rather than 5.49°, and so "sees" more LMCS interferers, with the same link gain when both antenna gain and free-space loss are taken into account. Thus **a system operating in the lower band would experience approximately 20 Log ( 5.9 / 5.49 ) or 0.62 dB more aggregate interference than one operating in the higher band.** Use of the lower band was assumed in the above analysis, leading to worst-case results.

### D.5.3 Variation in Proximity-Link Altitude

As a first approximation, altitude has no effect on the amount of interference received, because at a higher altitude the signal strength of a given interferer decreases by the square of the altitude, but the number of LMCS interferers increases by the same amount. However, there are secondary differences that lead to slight differences. One of these is the geometry differences at different altitudes. The second is the increased effect of a metropolitan area at lower altitudes, as modelled by Equation D.2 above. These differences tend to increase the interference at lower altitudes, as observed in the differences of up to 1.0 dB between the results in Tables D.2 and D.3. The conclusion is that there is a slight increase in interference at lower altitudes, and so the worst-case environment should be based on the proximity-link receiver being at its minimum altitude.

Based on Reference [4], the space station altitude range is 350 km to 430 km, and the altitude of remote users of a proximity-link may vary between 280 km and 500 km. However, when the remote user is at a lower altitude than the space station, its antenna is pointing **upward**, and so its antenna discrimination comes into play in protecting itself from interference from the ground. The worst case is in fact interference at the space station receiving interference from the ground while receiving